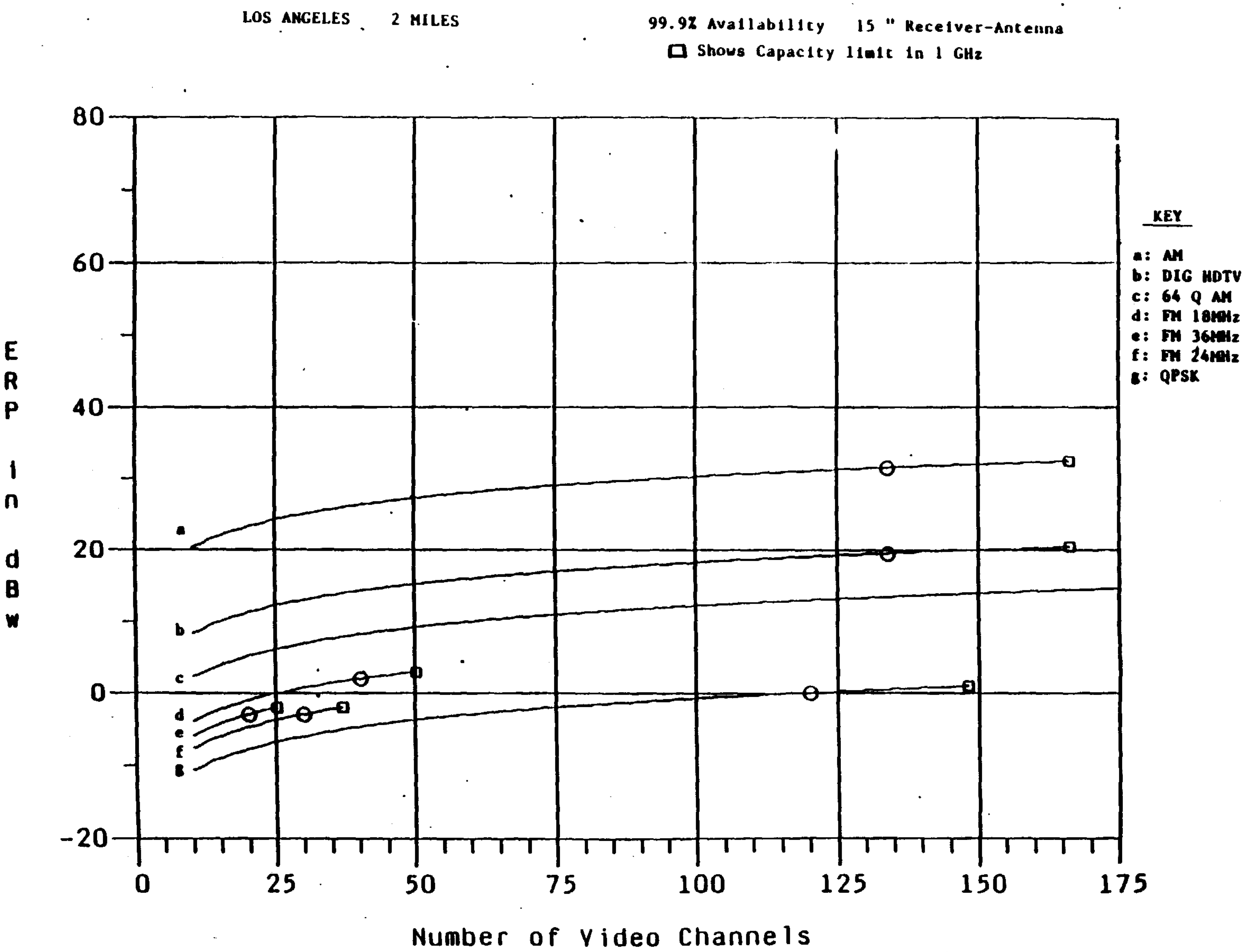


Figure I-5.1 ERP as a function of number of channels LA 2 miles.

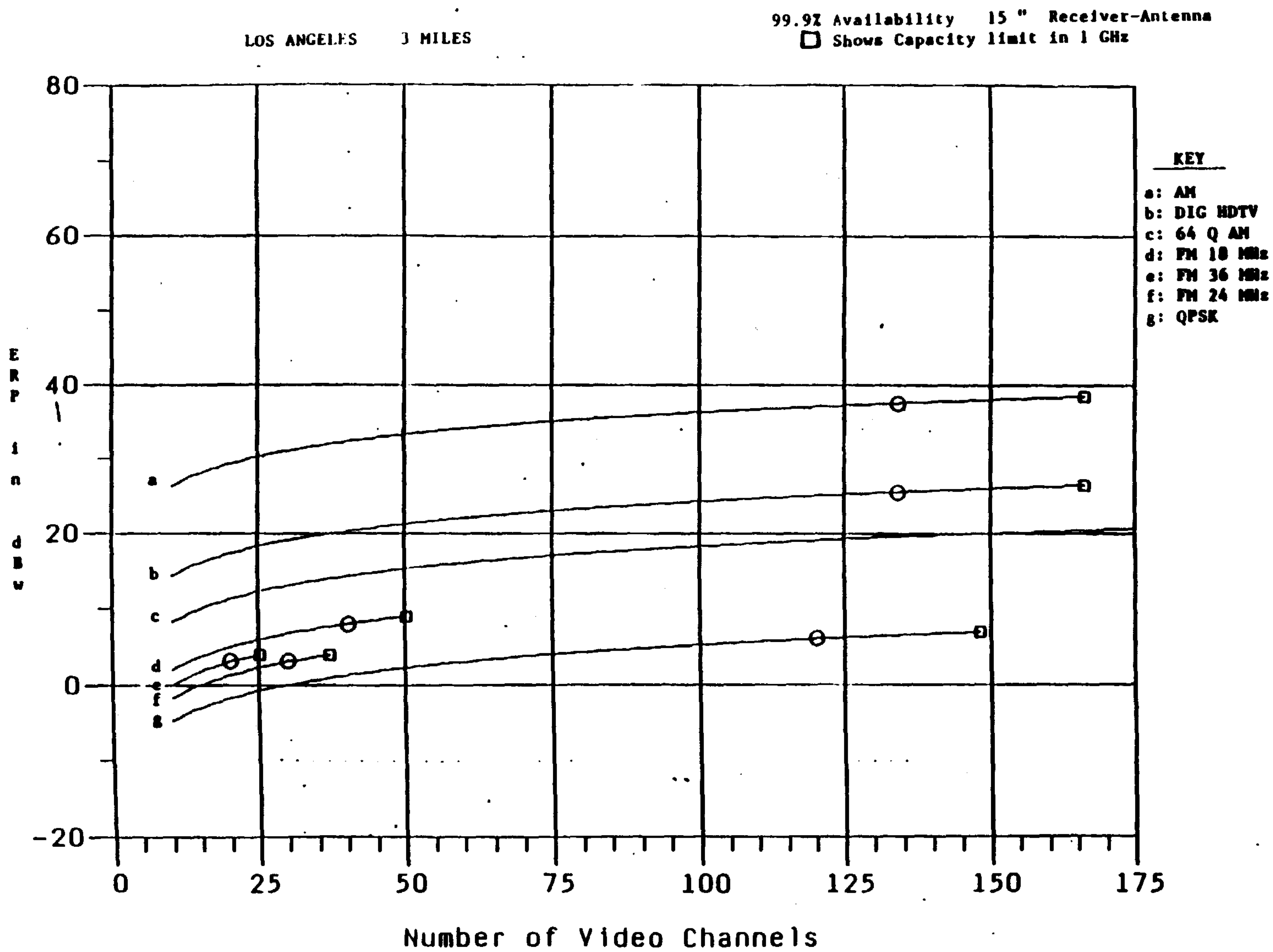


Figure I-5.1 ERP as a function of number of channels LA 3 miles.

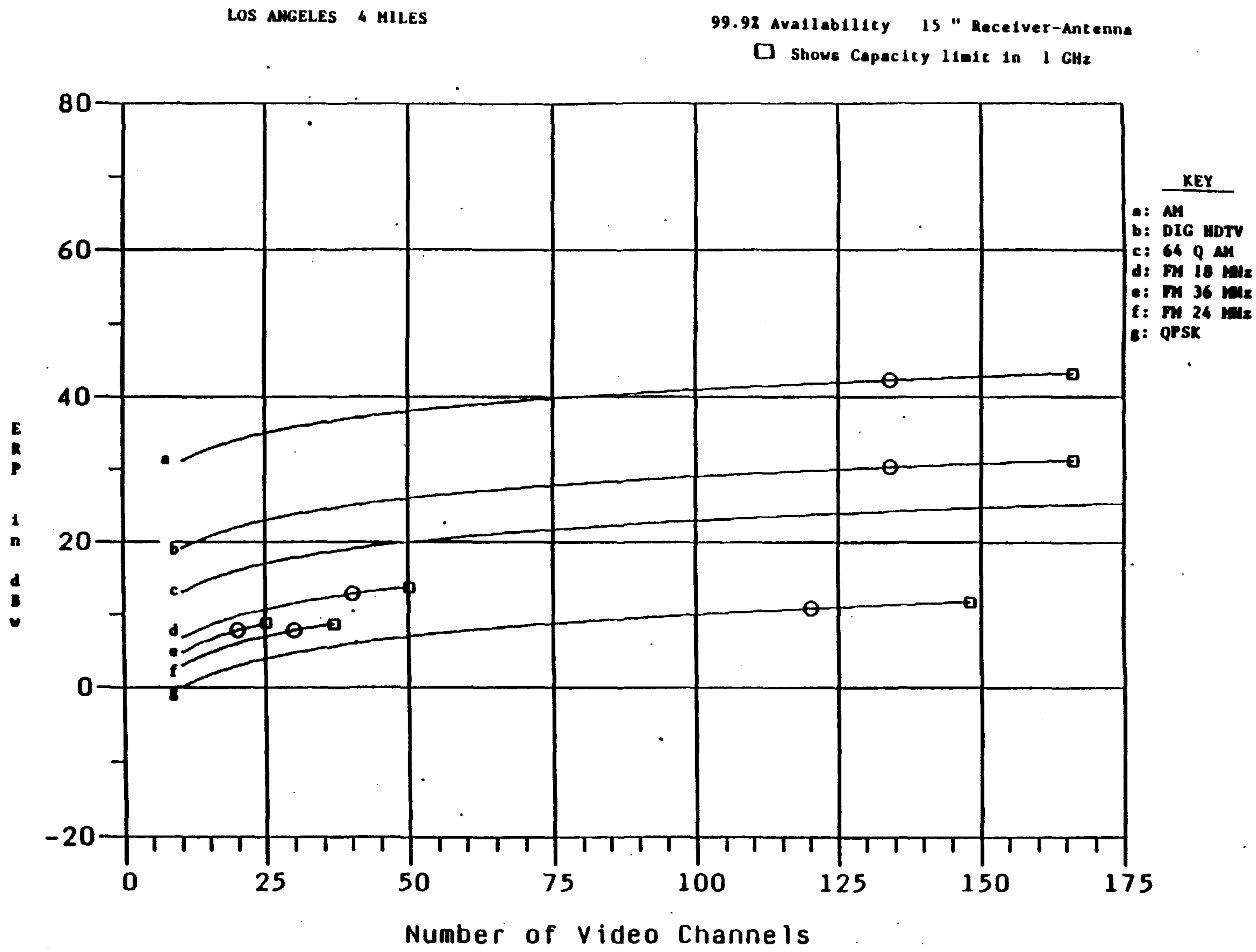


Figure I-5.1 ERP as a function of number of channels LA 4 miles.

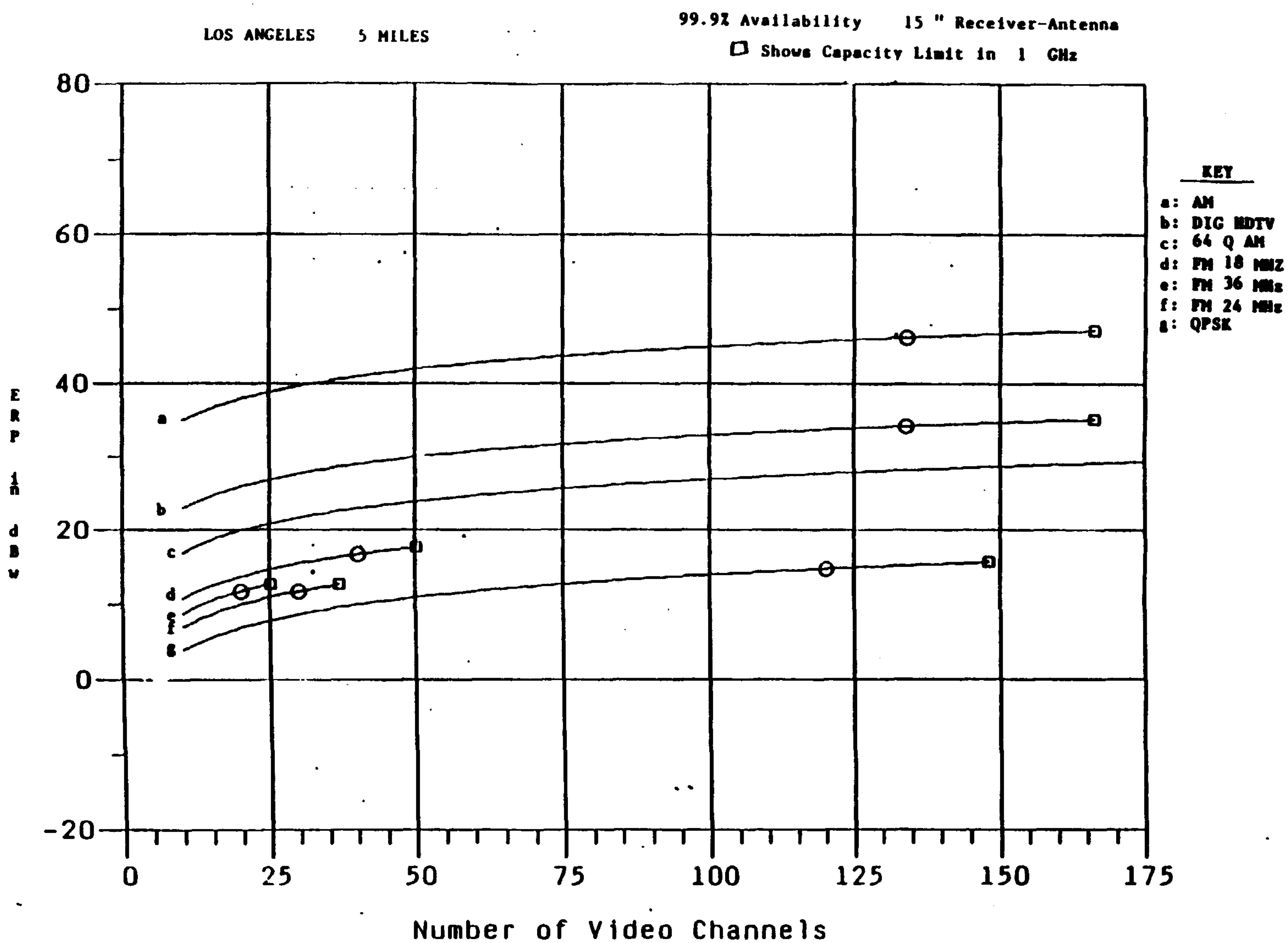


Figure I-5.1 ERP as a function of number of channels LA 5 miles.

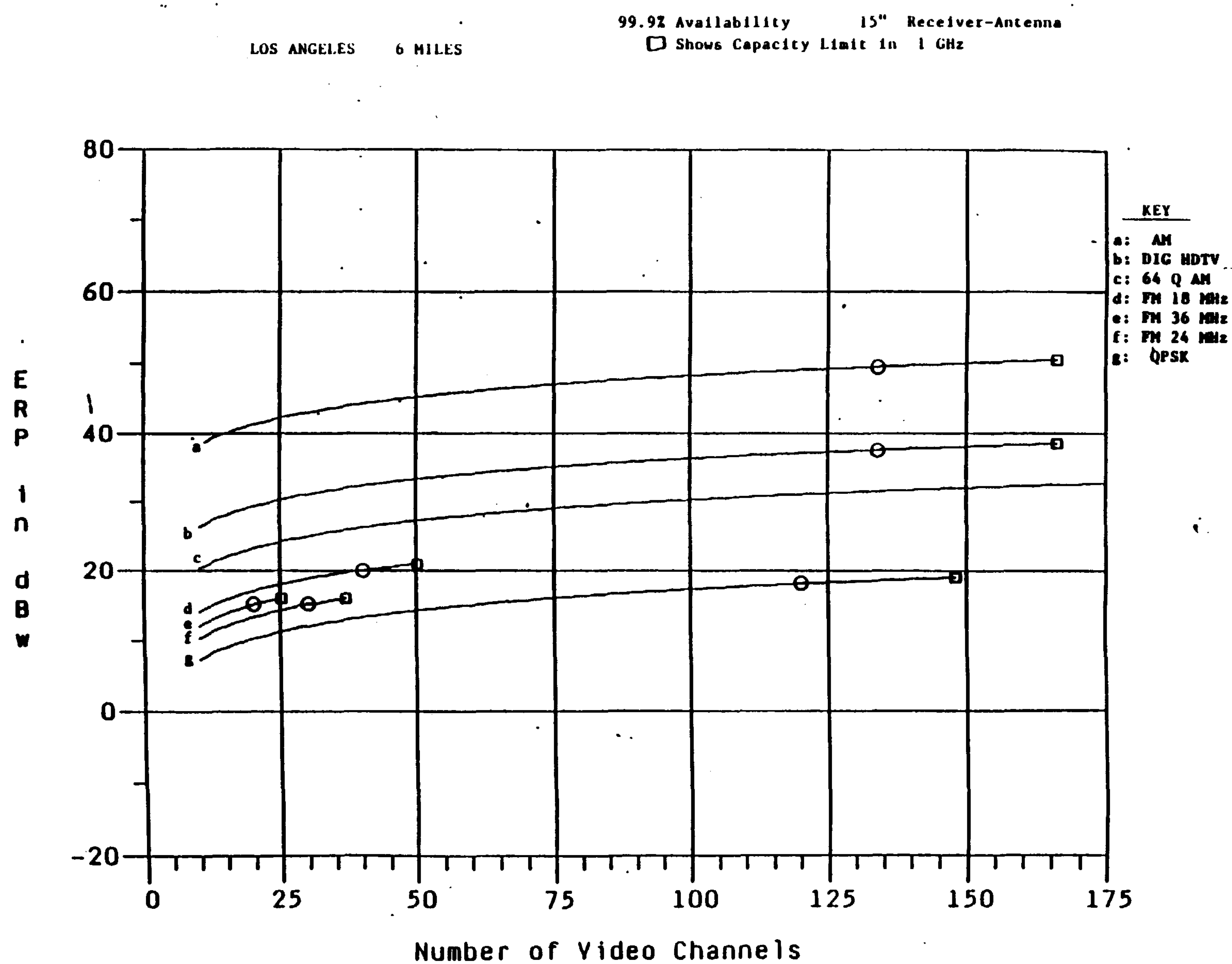


Figure I-5.1 ERP as a function of number of channels LA 6 miles.

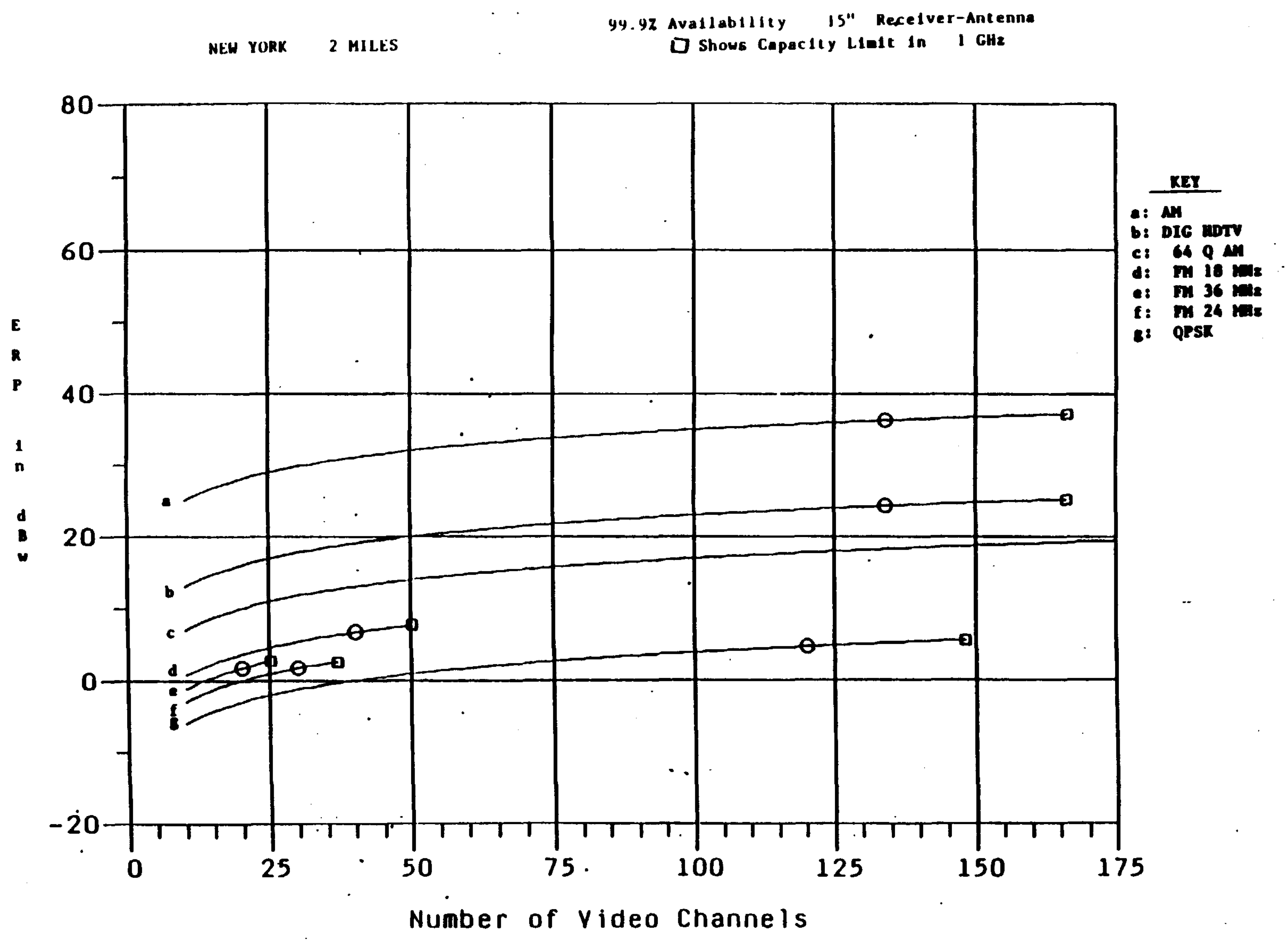


Figure I-5.1 ERP as a function of number of channels NY 2 miles.

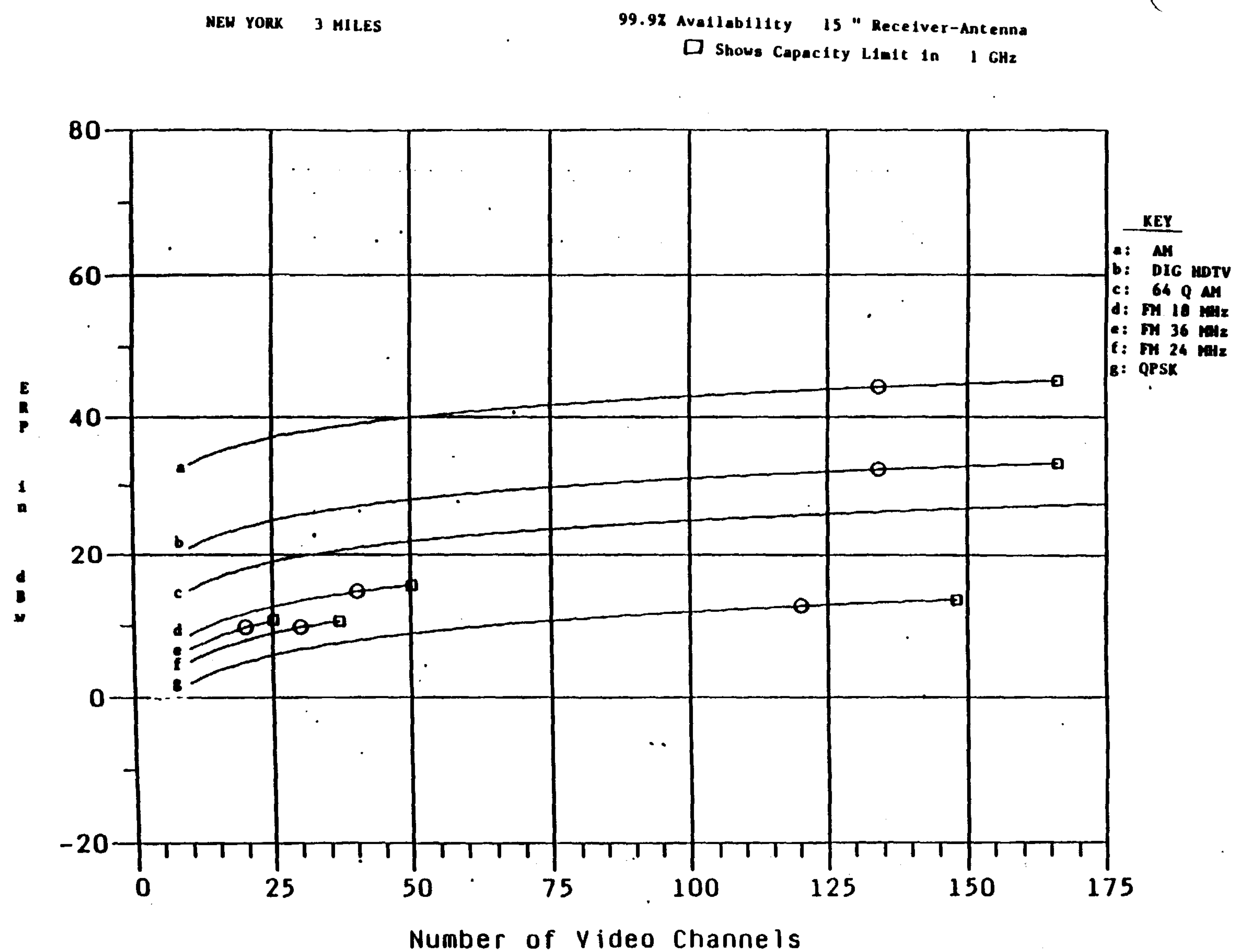


Figure I-5.1 ERP as a function of number of channels NY 3 miles.

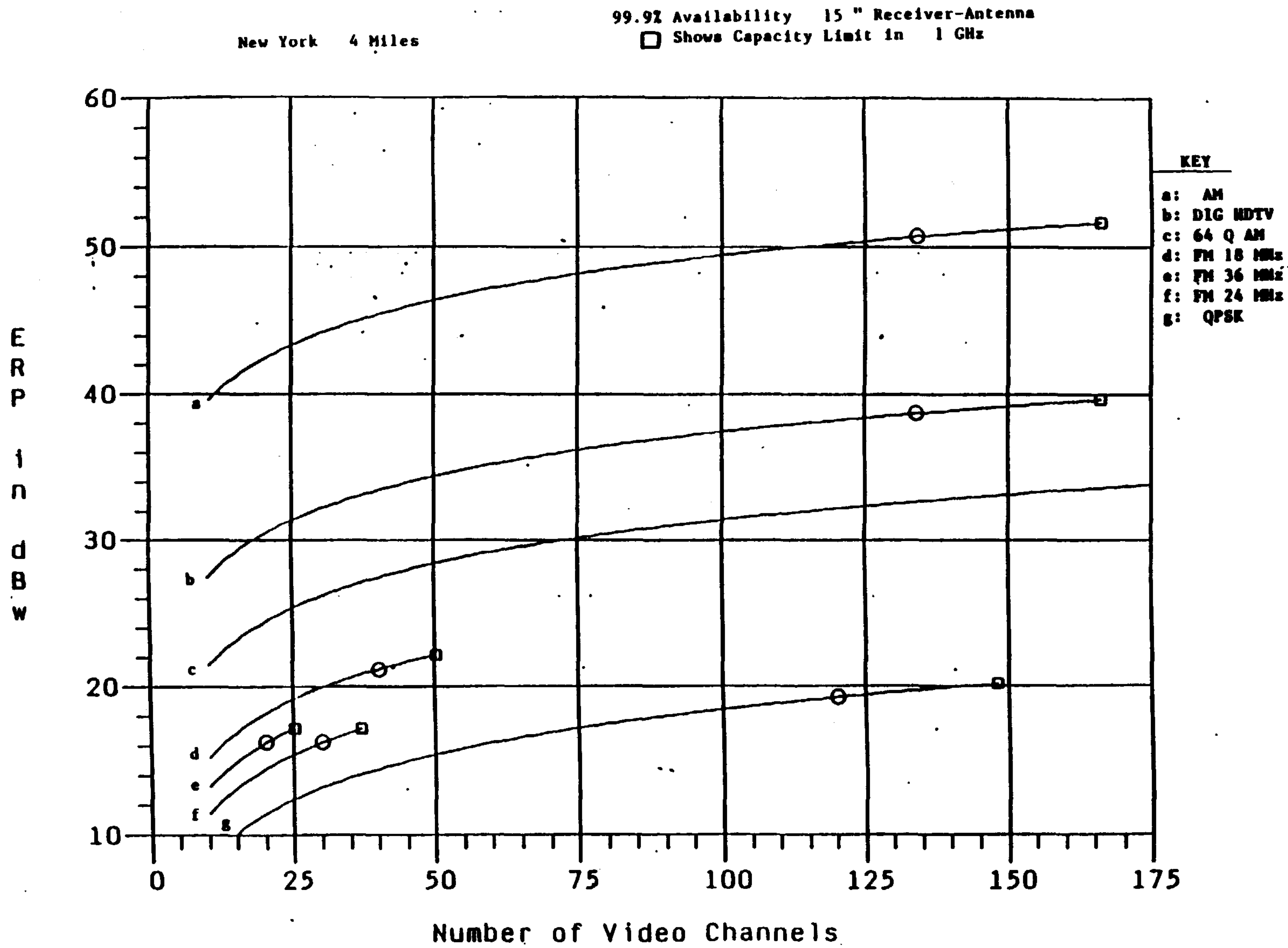


Figure I-5.1 ERP as a function of number of channels NY 4 miles.

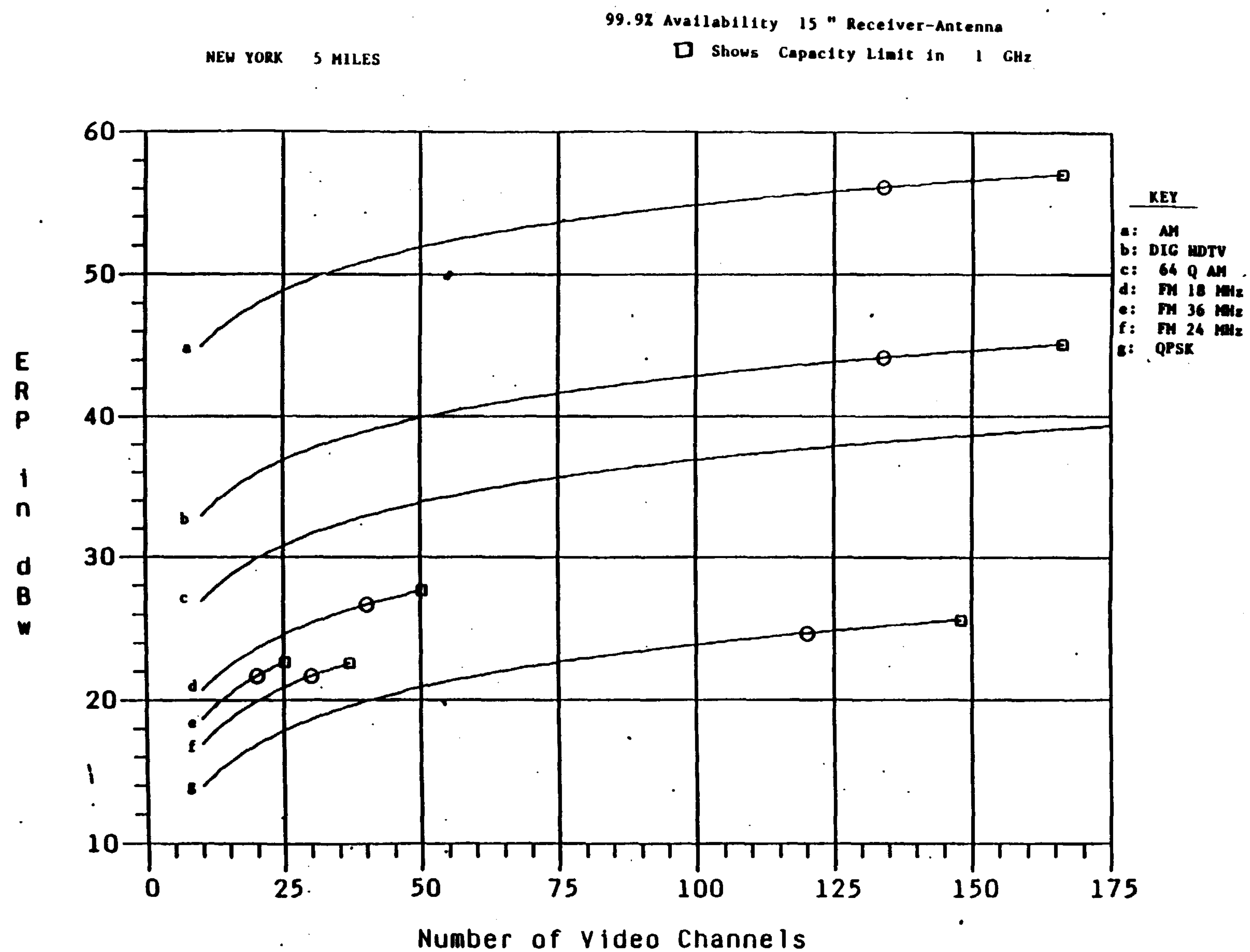


Figure I-5.1 ERP as a function of number of channels NY 5 miles.

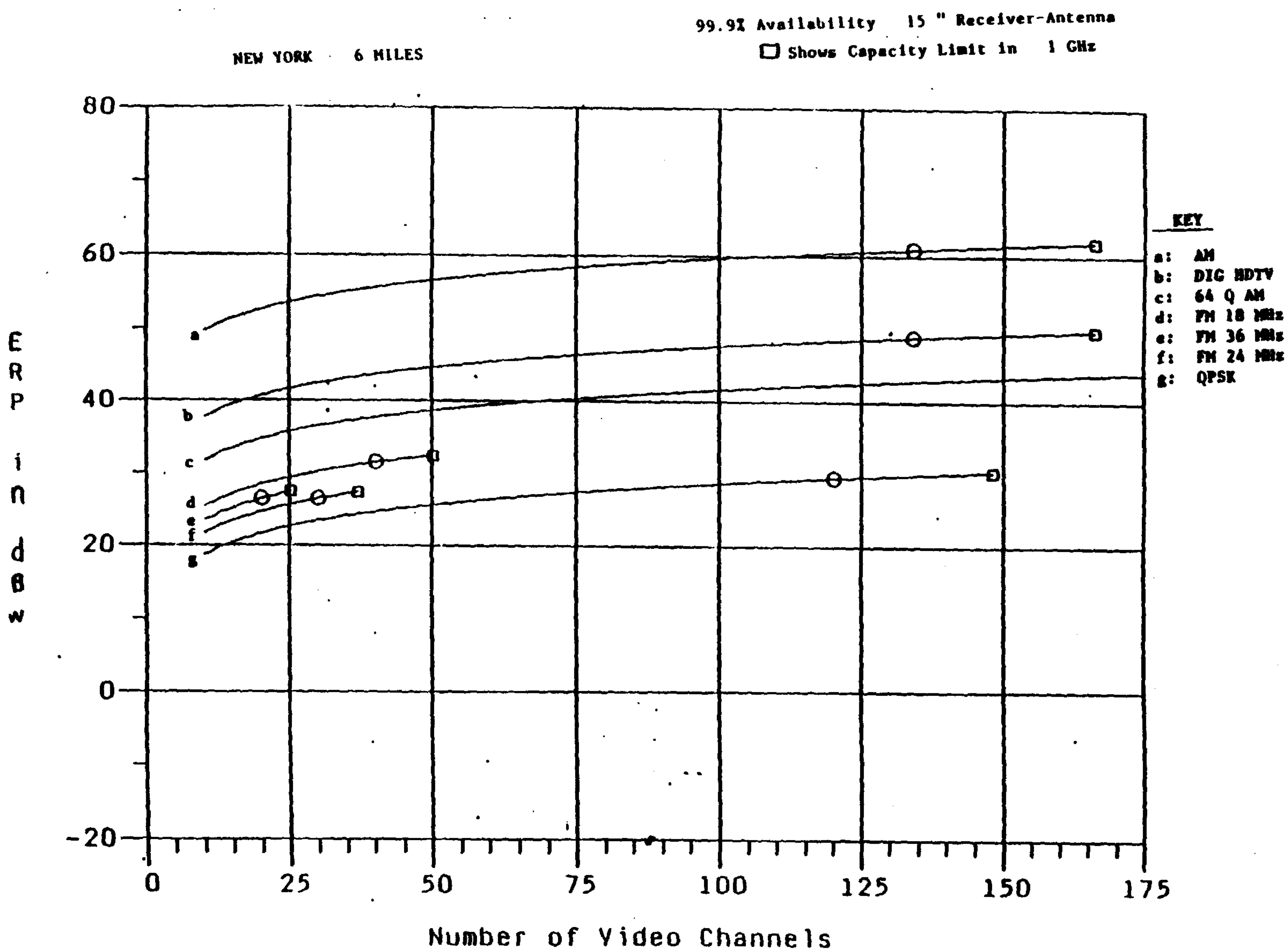


Figure I-5.1 ERP as a function of number of channels NY 6 miles.

6. FM Channel Capacities for 10W and 100W Transmitting Amplifiers

The previous section discussed the effective radiated power on a per carrier basis. The link equation can also be used to calculate the allowable distance between transmitter and receiver for a specified TWTA power level with the number of carriers as a parameter.

The receiving antenna is assumed to have a gain of 32 dB (7.5 in. dish) and the transmitting antenna a gain of 10 dB.

Let the transmitting system TWTA have a saturated power rating of 10 W CW. With 7 dB output backoff the CNR in a single channel is given by

$$CNR = 57.56 - 10 \log B - 10 \log n - 20 \log D - gD/(1 + 0.07151D)$$

where B is the carrier bandwidth in MHz, g is the constant 6.1639 for New York (3.4571 for Los Angeles), n is the number of carriers, and D is distance in miles. Setting B and CNR to 24 MHz and 8 dB, respectively, and n to 37 gives the coverage distance (radius). Similarly B, CNR and n can be set to 18 MHz, 13 dB and 50, respectively, and will give the coverage distance for 50 channels. The results of the diameter covered are as follow for 10W and 100W amplifiers.

10W CW amplifier:

50 carriers, 3.6 miles (New York), 4.8 miles (Los Angeles)

37 carriers, 4.6 miles (New York), 6.8 miles (Los Angeles)

100W CW amplifier:

50 carriers, 6.0 miles (New York), 9.0 miles (Los Angeles)

37 carriers, 7.6 miles (New York), 12.0 miles (Los Angeles)

Section II

CELLULARVISION SYSTEM

1. Introduction

The 27.5 to 29.5 GHz distributing system proposed by Suite 12 as described in U. S. patent 4,747,160 (as issued to Bernard B. Bossard) is a cellular system. It is comprised of an omni directional broadcast transmitting antenna in each cell and narrow beamwidth receiving antennas. It utilizes polarization, frequency diversity, and space diversity to optimize the use of frequency spectrum. In addition, the low transmitter power levels required and the FM technology used results in a system which can be easily expanded to additional adjacent cells without the need for additional frequency allocations. Small size repeaters are used to route the signal throughout a town in a manner similar to wire transmission.

Signal coverage to a large area can be provided using the cellular configuration shown in Fig. II-1.1. Each cell has a diameter of 6 to 12 miles. Transmitted signals in adjacent cells are cross-polarized. Within each cell shadow areas can be covered with a repeater that transmits signals on the opposite polarization or by simple passive reflectors. The consumer receiver antennas are either horn, parabolic, or planar (e.g. stripline) types with diameters ranging from 3 inches to 15 inches. They provide very narrow beam widths which results in virtually no multipath reception, and also provide a high degree of rejection to interference signals of the same polarization and frequencies, including those that are generated in diagonally opposite cells.

Within a cell, a frequency band of 1 GHz can be used to broadcast video channels, each of which occupy a 20 MHz bandwidth. The video channels can be broadcast with either vertical or horizontal polarization. The other polarization can be used for two-way services. An alternate plan is to allocate a frequency range on each polarization for broadcast services and, the remaining frequencies for two-way services. The actual frequency allocation of services should be determined by market forces and economics.

Signal transmission in adjacent cells is orthogonally polarized and frequency offset by 10 MHz (interleaved by 1/2 the channel bandwidth). This results in a 40 dB reduction in protection ratio and provides a minimum isolation between adjacent cells of 65 dB. The 65 dB of isolation is the sum of the isolation due to polarization (25 dB), frequency interleaving (15 dB), and antenna sidelobe suppression (25 dB). For those users who are located in areas diagonally opposite co-polarized cells (a very small percentage of total users) antennas have an inherent additional sidelobe suppression of 25 dB due to the diagonal angle.

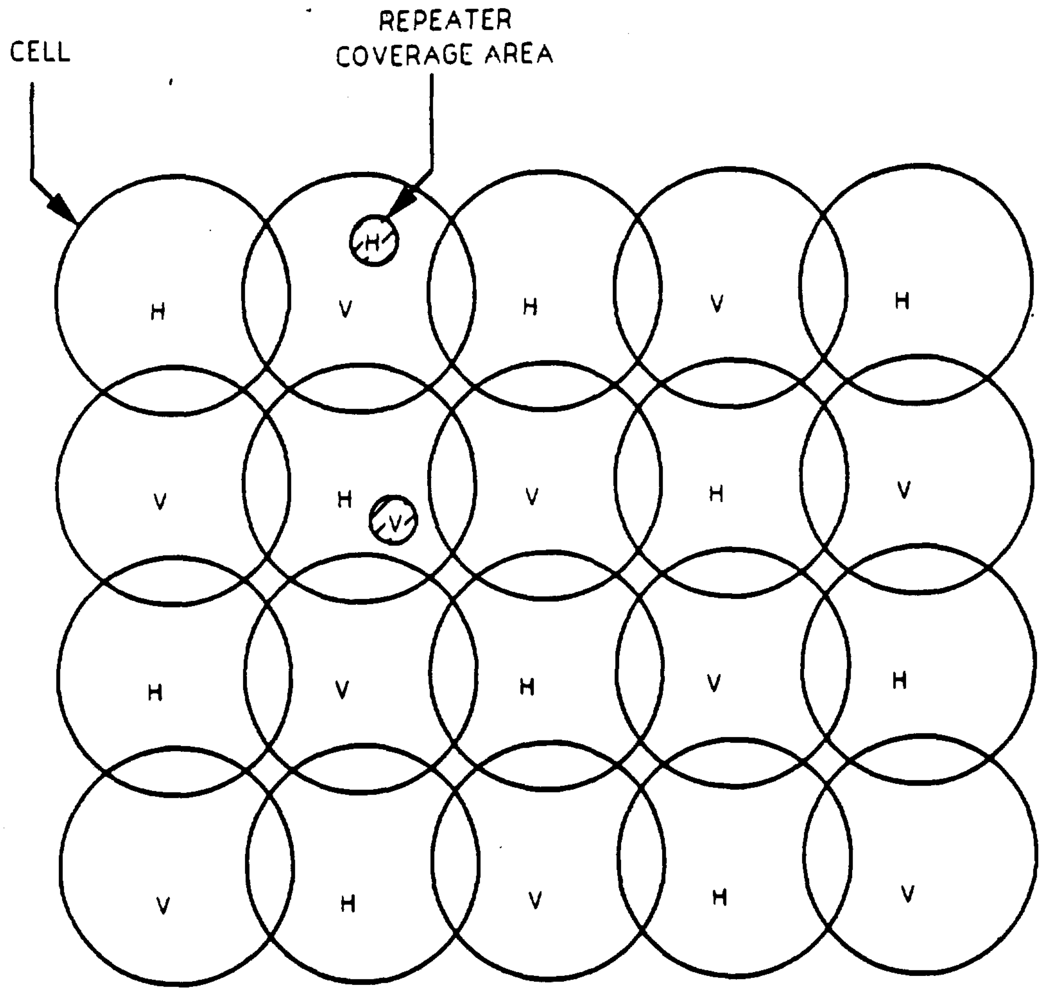
Within a cell there will be some receiver sites that are not in a direct line-of-sight path to the omni directional central transmitting antenna. Such shadow areas will be provided with repeaters. These repeaters can be active or passive. The distance covered by a passive repeater is up to a few thousand feet. Active low cost solid state repeaters can cover a range of up to two miles. The repeaters' antenna dimensions and power output will determine the size and shape of the area that is required to be covered.

2. Frequency Plan

At the node to subscriber transmitter, forty-nine video FM carriers are spaced 20 MHz apart. The two-way communication channels from node to subscriber are also 20 MHz wide, but are centered between the video carriers (i.e. have a 10 MHz offset from the video carriers) and are transmitted with a different polarization. The difference in polarization along with the channel offset provides an isolation of 40 dB between the video and two-way communication channels at the subscriber receiver. Subscriber to node two-way traffic channels are placed near the frequencies at which the video distribution carriers are located and are transmitted at the same polarization as the two-way traffic from the node to subscriber. It should be pointed out that the video transmissions utilize most of their allotted 20 MHz channels, but that each subscriber communication transmission utilizes only a very small portion of the 20 MHz channel allotted for their use.

As shown in Figure II-1.1 the signals may be horizontally or vertically polarized and are of the alternate polarization in adjacent cells. A 10 MHz frequency shift is provided between opposite cells.

The principal service is a forty-nine channel video distribution system. The possible secondary services consist of two-way narrowband analog and digital telephony, data, and teleconferencing residential and business traffic. The actual amount of the two-way traffic will be determined by market conditions, bandwidth required, and type of service provided.



H: Horizontal Polarization
V: Vertical Polarization

Figure II-1.1. Cellular Coverage and Polarization Plan

3. Transmitter Amplifier Issues

At the transmitter the following options exist for amplifiers and antennas (see Fig. II-3.1):

a) One amplifier with multicarrier input, and one antenna.

b) Multiple amplifiers (one per carrier), a multiplexer, and one antenna.

c) Multiple amplifiers and an array of antennas, with each element of the antenna fed by one amplifier. The signal combination takes place in space.

Option A (One Amplifier and One Antenna) Among the three, the first option is clearly the most desirable, because of hardware simplicity. Table I-5x.1 indicates the amplifier output power requirements for several coverage distances, assuming that the antenna gain is 6 and 18 dB (with 1 dB feed loss the effective gains are 5 and 17 dB). Clearly the amplifier output power required is extraordinarily high for AM, and lowest for QPSK modulation. Among analog modulation methods, FM with 24 MHz bandwidth is the most power efficient.

One issue that is extremely important for multicarrier operation is the intermodulation noise. Amplifier data supplied by Hye Crest (Fig. II-3.2) shows that at 8 dB output power backoff, the carrier-to-intermodulation noise ratio is 23 or 30 dB, depending upon not using or using a linearizer. The impact of this on FM or digital QPSK transmission is negligible, since they are designed to operate at a CNR of 8 to 12 dB under rain faded condition, and CNR of 22 to 33 dB in clear weather. The impact of a C/IM ratio of 30 dB, for instance, is to produce a SNR(TASO) of about 60 dB. The corresponding IM noise level is 10 dB lower than the thermal noise level in exceptionally good broadcast quality channels (SNR of 50 to 52 dB, TASO).

For AM channels, however, a C/IM ratio of 30 dB is completely inadequate. Typical required value for C/IM is [illegible]5 to 60 dB (using cable system practice as a benchmark). To meet the C/IM requirement of, say, 55 dB, it is required that the amplifier be operated at an output power backoff of 16 dB, assuming that C/IM increases at a rate of 3 dB per 1 dB increase in output backoff, beyond the 8 dB backoff value (which is optimistic). Hence the single-carrier saturating power rating of the amplifier should be 16 dB higher than the multicarrier output power required for AM operation. For 60 AM channels, the effective radiated power for all channels is 1.05 KW and 0.8 KW for the New York (4 mile distance) and Los Angeles (6 mile distance) systems, respectively, assuming that the antenna gain is 18 dB. Therefore, the single carrier saturation power rating values are 41.9 KW and 31.8 KW for the New York and Los Angeles systems. These values are far beyond the state of the art. If the Los Angeles system is assumed to have coverage of 3 miles, the amplifier rating is still too high (2 KW). Such high power amplifiers do not now exist, and are not likely to be made available. There is no known application for these types of power amplifiers in any communication system that we are aware of.

The situation is somewhat better for HDTV 6 MHz channels, since they require about 1/16th power of AM channels. Also the C/IM requirement can be set to 40 dB. Hence the output backoff required is 11 to 12 dB (which is optimistic); we will assume the 11 dB value here. Hence for the New York system the amplifier output power for 60 channels, and the single carrier saturating power rating, are 66.4 W and 836 W, assuming the antenna gain is 18 dB. In our opinion this high power is also not achievable. It is very unlikely that all 60 channels would carry HDTV signals in the near future. A more realistic assumption would be that there would be a mixture of standard and HDTV channels. The Hye Crest system, in its present configuration, could support a system of this type. For an all HDTV Los Angeles system with a 3 mile radius, the corresponding values are 3.2 W and 40.3 W. This power level is feasible.

Theoretically for 64 QAM-cable digital channels the above power levels are reduced by a factor of four, since it is assumed that each 6 MHz carrier is assumed to support four video channels. This technology is experimental at this time and very expensive.

Tables II-3.1 and II-3.2 show the achievable number of video channels for various candidate modulation methods for given values of amplifier single carrier saturation power. The assumed output backoff values are shown in the table. We believe that these are realistic values. Note that the distance specified in the tables is the radius of the cell. The cell diameter is twice this distance.

Option B (Multiple Amplifiers and One Antenna) In this option each individual video carrier is converted to RF in the 28 GHz band, amplified, and frequency division multiplexed with other channels using filters. This technique cannot be used here since each of the channels for any modulation are narrow relative to the microwave frequency. The consequence is that extremely high Q filters are required, which makes it impossible to implement.

Option C (Multiple Amplifiers and Antenna Arrays) In this option each video carrier is converted to RF in the 28 GHz band, amplified and fed to a single antenna element. Each element of the antenna array can be a horn antenna. The signal combination occurs in space. This technique is inappropriate for 6 MHz AM channels due to the extremely high power requirements and very short range for each channel. In addition, it has other deficiencies which are intrinsic to an AM system. The degradation of signal to noise if a repeater, which is necessary to cover shadow areas, is used; and the inability to use the same frequency within a cell due to AM's inability to reject a low level interfering signal at the same frequency. The two major technical problems associated with AM modulation which are very difficult to overcome are:

1. The amplifier should be sufficiently linear to allow transmission of a (single) NTSC over-the-air standard signal, i.e., cross-modulation products among color, sound and picture carrier are low (-50 dB relative to the picture carrier). This is a very difficult goal to achieve due to the power requirements. For example, Table II-3.2(d) indicates, that in the NY area, the transmission of just a single AM channel requires 250 Watts of power to obtain a range of only two miles.

2. The antenna array should be such that signals from each element do not interfere with each other. This is difficult due to the large power requirements. It requires substantial isolation for ech antenna transmitting element. The narrow beamwidth elements which must be used will result in very small coverage areas.

The low power and backoff requirements for FM modulation enable the technique to be implemented. Option A using FM modulation is the most desirable solution from a performance and cost point of view.

Table II-3.1 (a)

NUMBER OF CHANNELS THAT CAN BE TRANSMITTED

Modulation method: FM, 36 MHz bandwidth
Maximum number of video channels that can be carried in 1 GHz: 25
Amplifier outout backoff: 8 dB
Amplifier power rating corresponds to single carrier saturation.
Rain Availability: 99.9 %

		Video channel capacity for specified distance (mi									
		Los Angeles					New York				
Amplifier power rating, W	Antenna gain, dB	2mi	3mi	4mi	5mi	6mi	2mi	3mi	4mi	5mi	6mi
10	18	25	25	25	25	25	25	25	25	10	3
10	6	25	25	16	6	3	25	10	2	0	0
25	18	25	25	25	25	25	25	25	25	25	8
25	6	25	25	25	16	7	25	25	5	1	0
50	18	25	25	25	25	25	25	25	25	25	17
50	6	25	25	25	25	15	25	25	11	3	1
100	18	25	25	25	25	25	25	25	25	25	25
100	6	25	25	25	25	25	25	25	23	6	2
250	18	25	25	25	25	25	25	25	25	25	25
250	6	25	25	25	25	25	25	25	25	16	5
500	18	25	25	25	25	25	25	25	25	25	25
500	6	25	25	25	25	25	25	25	25	25	11
750	18	25	25	25	25	25	25	25	25	25	25
750	6	25	25	25	25	25	25	25	25	25	16
1000	18	25	25	25	25	25	25	25	25	25	25
1000	6	25	25	25	25	25	25	25	25	25	22

Table II-3.1 (b)

NUMBER OF CHANNELS THAT CAN BE TRANSMITTED

Modulation method: FM, 24 MHz bandwidth
Maximum number of video channels that can be carried in 1 GHz: 37
Amplifier outout backoff: 8 dB
Amplifier power rating corresponds to single carrier saturation.
Rain Availability: 99.9 %

Video channel capacity for specified distance (mi)

Amplifier power rating, W	Antenna gain, dB	Los Angeles					New York				
		2mi	3mi	4mi	5mi	6mi	2mi	3mi	4mi	5mi	6mi
10	18	37	37	37	37	37	37	37	37	16	5
10	6	37	37	24	10	4	37	15	3	1	0
25	18	37	37	37	37	37	37	37	37	37	13
25	6	37	37	37	25	11	37	37	8	2	0
50	18	37	37	37	37	37	37	37	37	37	26
50	6	37	37	37	37	23	37	37	17	5	1
100	18	37	37	37	37	37	37	37	37	37	37
100	6	37	37	37	37	37	37	37	35	10	3
250	18	37	37	37	37	37	37	37	37	37	37
250	6	37	37	37	37	37	37	37	37	25	8
500	18	37	37	37	37	37	37	37	37	37	37
500	6	37	37	37	37	37	37	37	37	37	16
750	18	37	37	37	37	37	37	37	37	37	37
750	6	37	37	37	37	37	37	37	37	37	25
1000	18	37	37	37	37	37	37	37	37	37	37
1000	6	37	37	37	37	37	37	37	37	37	33

Table II-3.1 (c)

NUMBER OF CHANNELS THAT CAN BE TRANSMITTED

Modulation method: FM, 18 MHz bandwidth
Maximum number of video channels that can be carried in 1 GHz: 50
Amplifier outout backoff: 8 dB
Amplifier power rating corresponds to single carrier saturation.
Rain Availability: 99.9 %

		Video channel capacity for specified distance (mi)									
Amplifier power rating, W	Antenna gain, dB	Los Angeles					New York				
		2mi	3mi	4mi	5mi	6mi	2mi	3mi	4mi	5mi	6mi
10	18	50	50	50	50	31	50	50	24	6	2
10	6	50	31	10	4	1	41	6	1	0	0
25	18	50	50	50	50	50	50	50	50	17	5
25	6	50	50	26	10	4	50	16	3	1	0
50	18	50	50	50	50	50	50	50	50	34	11
50	6	50	50	50	21	9	50	33	7	2	0
100	18	50	50	50	50	50	50	50	50	50	22
100	6	50	50	50	42	19	50	50	15	4	1
250	18	50	50	50	50	50	50	50	50	50	50
250	6	50	50	50	50	49	50	50	38	10	3
500	18	50	50	50	50	50	50	50	50	50	50
500	6	50	50	50	50	50	50	50	50	21	7
750	18	50	50	50	50	50	50	50	50	50	50
750	6	50	50	50	50	50	50	50	50	32	10
1000	18	50	50	50	50	50	50	50	50	50	50
1000	6	50	50	50	50	50	50	50	50	43	14

Table II-3.1(d)

NUMBER OF CHANNELS THAT CAN BE TRANSMITTED

Modulation method: AM, 6 MHz bandwidth
Maximum number of video channels that can be carried in 1 GHz: 166
Amplifier outout backoff: 20 dB
Amplifier power rating corresponds to single carrier saturation.
Rain Availability: 99.9 %

		Video channel capacity for specified distance (mi)									
		Los Angeles					New York				
Amplifier power rating, W	Antenna gain, dB	2mi	3mi	4mi	5mi	6mi	2mi	3mi	4mi	5mi	6mi
10	18	0	0	0	0	0	0	0	0	0	0
10	6	0	0	0	0	0	0	0	0	0	0
25	18	1	0	0	0	0	0	0	0	0	0
25	6	0	0	0	0	0	0	0	0	0	0
50	18	2	0	0	0	0	0	0	0	0	0
50	6	0	0	0	0	0	0	0	0	0	0
100	18	4	1	0	0	0	1	0	0	0	0
100	6	0	0	0	0	0	0	0	0	0	0
250	18	11	2	0	0	0	3	0	0	0	0
250	6	0	0	0	0	0	0	0	0	0	0
500	18	23	5	1	0	0	7	1	0	0	0
500	6	1	0	0	0	0	0	0	0	0	0
750	18	35	8	2	1	0	11	1	0	0	0
750	6	2	0	0	0	0	0	0	0	0	0
1000	18	46	11	3	1	0	15	2	0	0	0
1000	6	2	0	0	0	0	0	0	0	0	0

Table II-3.1 (e)

NUMBER OF CHANNELS THAT CAN BE TRANSMITTED

Modulation method: Digital HDTV, 6 MHz bandwidth
Maximum number of video channels that can be carried in 1 GHz: 166
Amplifier outout backoff: 13 dB
Amplifier power rating corresponds to single carrier saturation.
Rain Availability: 99.9 %

Amplifier power rating, W	Antenna gain, dB	Video channel capacity for specified distance (mi)									
		Los Angeles					New York				
		2mi	3mi	4mi	5mi	6mi	2mi	3mi	4mi	5mi	6mi
10	18	37	9	3	1	0	12	1	0	0	0
10	6	2	0	0	0	0	0	0	0	0	0
25	18	93	23	7	3	1	31	4	1	0	0
25	6	5	1	0	0	0	1	0	0	0	0
50	18	166	46	15	6	2	62	9	2	0	0
50	6	11	2	0	0	0	3	0	0	0	0
100	18	166	93	31	12	5	125	19	4	1	0
100	6	23	5	1	0	0	7	1	0	0	0
250	18	166	166	78	31	14	166	49	11	3	1
250	6	58	14	4	2	0	19	3	0	0	0
500	18	166	166	157	63	29	166	99	22	6	2
500	6	117	29	9	4	1	39	6	1	0	0
750	18	166	166	166	95	44	166	149	33	9	3
750	6	166	44	14	6	2	59	9	2	0	0
1000	18	166	166	166	127	58	166	166	45	12	4
1000	6	166	58	19	8	3	78	12	2	0	0

Table II-3.1 (f)

NUMBER OF CHANNELS THAT CAN BE TRANSMITTED

Modulation method: 64 QAM-digital cable, 6 MHz bandwidth
Maximum number of video channels that can be carried in 1 GHz: 664
Amplifier outout backoff: 13 dB
Amplifier power rating corresponds to single carrier saturation.
Rain Availability: 99.9 %

		Video channel capacity for specified distance (mi)									
		Los Angeles					New York				
Amplifier power rating, W	Antenna gain, dB	2mi	3mi	4mi	5mi	6mi	2mi	3mi	4mi	5mi	6mi
10	18	148	36	12	4	0	48	4	0	0	0
10	6	8	0	0	0	0	0	0	0	0	0
25	18	372	92	28	12	4	124	16	4	0	0
25	6	20	4	0	0	0	4	0	0	0	0
50	18	664	184	60	24	8	248	36	8	0	0
50	6	44	8	0	0	0	12	0	0	0	0
100	18	664	372	124	48	20	500	76	16	4	0
100	6	92	20	4	0	0	28	4	0	0	0
250	18	664	664	312	124	56	664	196	44	12	4
250	6	232	56	16	8	0	76	12	0	0	0
500	18	664	664	628	252	116	664	396	88	24	8
500	6	468	116	36	16	4	156	24	4	0	0
750	18	664	664	664	380	176	664	596	132	36	12
750	6	664	176	56	24	8	236	36	8	0	0
1000	18	664	664	664	508	232	664	664	180	48	16
1000	6	664	232	76	32	12	312	48	8	0	0